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THESIS

COMPARATIVE ANALYSIS OF INTERMEDIATE LEVEL MAINTENANCE REPAIR PROCESS

by

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June 2002

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COMPARATIVE ANALYSIS OF INTERMEDIATE LEVEL MAINTENANCE REPAIR PROCESS

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ABSTRACT

This study investigated the impact of Consolidated Automated Support System on the intermediate level of naval aviation maintenance repair process. Repair process analysis can be used as a management tool in measuring process capability and determining how well process outputs are meeting the external customer requirements. This comparative study of the pre-CASS and post-CASS mean time between failure and mean time to repair process output data results showed significant process improvements. The use of this methodology can be incorporated at all level of maintenance. This approach can result in wide scale changes in repair process analysis, as well as, impact future acquisition and weapon system support decisions. Recommendations for changes in Aviation Maintenance Management repair process and data collection methods are included along with suggestions for further research.

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I. INTRODUCTION

A. THE PROBLEM

The Consolidated Automated Support System (CASS) was fielded in 1993 to replace legacy Computerized Automated Test Equipment (ATE) used at the I-Level to solve the supportability and maintainability problems. Prior to the introduction of CASS, excessive throughput capacity (MTTR) plagued the intermediate maintenance activities, particularly the Radar Station Test Set (RSTS) that was used to test the AN/APG-65 series radar. The excessive RSTS repair process time had an overwhelming impact on aircraft readiness and was one of the driving forces behind the change in test equipment. Following major system upgrades, maintenance data reports indicates that the APG-65 series radars are still experiencing an increase in MTTR, while simultaneously experiencing a decrease in MTBF.

B. SOLUTION PROPOSED BY THIS THESIS

Logisticians must collect data that allows managers to scrutinize the repair process in detail and develop process control measures that track variability between the projected and actual MTBF and MTTR rates. Furthermore, managers must set control limits of acceptable variability in key performance measures, monitor actual performance, and correct any abnormal variability. Then institute methods for measuring, analyzing and controlling variability in actual performance over time. Finally, a culture that allows managers to publicize their concerns early on must be

encouraged. Open and honest communication is essential in optimizing the maintainability and supportability aspects of weapon system throughout its life cycle.

C. WHAT WILL HAPPEN IF THE PROBLEM IS NOT SOLVED?

The F/A-18 is considered the most advanced and capable aircraft in the world partly due to its advanced radar and avionics system capabilities. However, the APG-65 radar system used in this aircraft is a leading mission degrader.

It is a given, as weapons system age, they will require additional resources and place a higher than normal demand on the repair process to restore them operationally. Nevertheless, this system is unexpectedly experiencing rising life cycle costs, increased frequency of failures and increased time to repair. During this period, commands outfitted with the aging APG-65 system and more importantly, the Intermediate Maintenance Department responsible for supporting them will be particularly affected. If these concerns are not addressed, commands will be affected by increased workloads, higher cannibalizations rates, reduced mission readiness rates; moreover, the cost to maintain this system will continue to escalate.

D. BACKGROUND

Meeting the threats of the future is becoming difficult. Military leaders are charged with balancing today's operational requirements while concurrently ensuring we are prepared for any contingency. (NAVAIR, online) An environment of declining resources, aging weapon systems, increased operational tempo and escalating life cycle cost is the reality. To sustain superior war fighting capabilities in this environment,

logisticians must implement analytical approaches to improve processes that will serve the immediate requirements of the fleet.

The continued study of the maintenance repair processes allows managers to examine a weapon system throughout its life cycle, producing results that can serve as a useful analytical tool. These results can be used to measure the effectiveness of previous modifications, identify problem areas, determine what is required to extend existing system capabilities, as well as, answer the question; what are the requirements for new systems that improve readiness? Repair process analyses can lead the way to achieve our objectives. It can guide the logistician to focus on performance parameters from the early phases of the procurement process to the postproduction support phase.

The primary goal of a maintenance manager is to improve fleet readiness while preserving quality. Process analysis is an essential step toward achieving that objective. The F/A-18 weapon platform is in transition with steadily declining readiness rates and rising maintenance man-hour/flight hours. A re-examination of the intermediate level repair process may generate viable alternatives that could yield high returns in supportability and maintainability. Evidence suggests that the dynamics of the repair process can offer alternative solutions to the support problems plaguing the repair process.

This thesis used graphical analysis and descriptive statistics to depict the results. This study used archival data to compare the mean difference of the intermediate level maintenance repair process output, focusing on the AN/APG-65 radar system.

The objective here is to compare the intermediate level maintenance output for the AN/APG-65 radar system before and after the implementation of Consolidated Automated Support System to determine whether CASS improves the repair process.

E. RESEARCH QUESTIONS

1. Primary research question:

Has the MTTR for the APG-65 radar system at AIMD, NAS Lemoore change since the fielding of CASS?

2. Secondary research question:

Did the MTBF for the APG-65 radar system/components change since the fielding of CASS?

II. DATA COLLECTION AND METHODOLOGY

A. CONDUCT OF THE STUDY

The purpose of this study is to perform a before and after comparison of the mean difference in turnaround time and repair time for the radar system since the fielding of CASS at AIMD, NAS Lemoore. This study analyzed any subsequent changes in the repair process. To facilitate our efforts to accurately measure the repair process output, each component processed through the repair cycle had to be traced to a user activity to measure the actual mean time between failures. From the available organizational squadrons that operate at NAS Lemoore equipped with this system, Strike Fighter Squadron 125 (VFA-125) was chosen for this analysis.

VFA-125 is the F/A-18 training squadron that is home ported at NAS Lemoore. To accomplish its mission, VFA-125 does send detachments to aircraft carriers and other shore bases for student training. However, these detachments are supported by supply pack-up kits with the non-RFI retrograde returned to AIMD Lemoore for repair actions. Therefore, the selection of this site resulted from our search for an organization that would enable us to examine changes in the repair process to determine if CASS had an effect on MTTR and MTBF of the F/A-18 radar system components.

1. Experimental Design Development

Having visited AIMD Lemoore, we developed a better understanding of the process and devise a means to evaluate the repair process that was relevant to the customer, as well as, the provider. Therefore, we decided to the measure the mean

difference of the output. Information to measure total turnaround time and mean time between failures were collected and evaluated for the radar system. Archival MDS data was collected from the Naval Aviation Logistic Data Analysis (NALDA) system. The period selected for review, January 1990 to December 1997. The data set contained information to calculate MTBF and MTTR, sorted by calendar year: annual flight hours; verified failures; AIMD days; MMHRS; EMT and AWM.

B. THE SAMPLE

At AIMD Lemoore, the CASS workstation used to repair the five components of the F/A-18 radar system resides in Work Center 63D. This study selected these components from the period of 1 January 1990 to 31 December 1997. There populations were then divided for the before and after comparison by separating them on 31 December 1993. The populations are then defined as:

- Before CASS -1 January 1990 to 31 December 1993
- After CASS -1 January 1994 to 31 December 1997

The MTTR data was assembled in fields that were used to build the database for analysis. The fields included the elapse maintenance time, awaiting maintenance time, maintenance man-hours and the total AIMD days. By using these database fields, the summary statistics were limited to the total time it took in the repair cycle without considering any awaiting parts time. We were sure there was some awaiting parts time, the data is also, tracked in the 3M system; however, this data field was not included in our data set. For the purposes of this study, we decided not to derive the information

from the data sample provided in fear of inducing more errors than utility. Thus, the summary statistic is limited to strictly the total time required to repair and restore the component to full operating status.

C. INTERNAL/EXTERNAL PROCESS MEASURES

We also gathered archival data to measure the quality and repair rate of the components issued RFI to see what effect, if any, CASS had on quality and work center repair capability. The two measures of quality and capability that were selected were the mean time between failures (MTBF) and the supporting squadrons "Y" code rates for the components repaired. The measures of capability of the repair cycle output that were selected were the MTTR and BCM rate of components repaired.

1. MTBF-External Measure

MTBF is a reliability factor that is used to determine the frequency of maintenance. In general, as the reliability of a system increases, the frequency of maintenance will decrease, and as the reliability of the system decreases, the frequency of maintenance will increase. To determine if CASS had an effect on the MTBF of the systems, a before and after comparison was made of the five radar components repaired. A comparison of MTBF over time does not strictly isolate the effect that CASS has on components. Other factors such as system upgrades and modifications can change the MTBF of a component. For this reason, every attempt was made to ensure that the components selected would not have other factors that would bias the results.

The 3M-system database was used to collect the data for this analysis. The analysis was based on data from the following period:

- Before CASS -1 January 1990 to 31 December 1993
- After CASS -1 January 1994 to 31 December 1997

All five components processed through the local repair cycle were included in this analysis. The data was obtained by sorting the data base fields on VFA-125 organizational code (PE4) and the five different radar work unit codes. These sorts determined the total number of failure that VFA-125 had for each component during the selected periods. For these same periods, VFA-125's total flight hours were calculated. These two number were then used to compute the rate at which failures occurs in a specified interval, or the failure rate. The failure data for VFA-125 consisted of verified failures. The failure rate was then used to determine the MTBF for selected radar components. MTBF was then studied to determine what affect CASS had on the reliability of the system.

2. "Y" Code Rates-External Measure

A "Y" is a "when discovered code". Organizational squadrons use this status code to document a component that is received from supply in a non-RFI condition. For a component to be "Y" coded it must fail its initial maintenance operational check upon installation in the aircraft. There are many reasons for an item being "Y" coded. The component can be broken in the storage facility or while in transit, passed on by the AIMD as RFI when in fact an undetected fault still exists, or damage upon installation by

the organizational level. The "Y" code rate was studied to determine if since the implementation of CASS to the repair process if it had an affect on the probability of a component passing a test on the bench when in reality it was bad. A before and after comparison of the "Y" code rates was used to determine if there was a significant change in the rate. The data used for this analysis was for the period:

- Before CASS -1 January 1990 to 31 December 1993
- After CASS -1 January 1994 to 31 December 1997

This analysis was based on all five components that were repaired in the radar shop. The data was obtained by using the 3M database provided by NAVAIR. All "Y" codes were totaled for each period. This number was then used to determine the total "Y" code percentage for each period. The following formula was used for these calculations:

$$\text{Percent “Y” code} = \frac{\#\ \text{“Y” Codes}}{\text{Total }\#\text{ Repaired}}$$

The fact that an item is "Y" coded does not necessarily mean the component is in fact faulty. Poor trouble-shooting by the organizational level, an anomaly in the system or bad test equipment can also lead to "Y" codes and result in an unfair bias against the AIMD.

3. MTTR-Internal Measure

MTTR is a measure of the time-to-repair of a repair cycle. The frequency of maintenance for a component is highly dependent on the reliability of that component.

To determine if CASS had an effect on the MTTR of components, a before and after comparison was made of the five radar components repaired. A rigid comparison of MTTR over time will not isolate the effect that CASS had on the components repaired. Other factors such as training, manpower, spare parts, degradation over time, complexity of failures, also, affect the MTTR of a component. The 3M-system database was used to collect the data for this analysis. The analysis was based on data from the following period:

- Before CASS -1 January 1990 to 31 December 1993
- After CASS -1 January 1994 to 31 December 1997

Each components processed through the repair cycle was included in this analysis. The data was obtained by sorting the data base fields on VFA-125 organizational code (PE4) and the five different radar work unit codes. These sorts determined the total number of failure that VFA-125 had for each component during the selected periods. For these same periods, the average TAT the repair cycle was calculated. The failure data factors for VFA-125 included EMT, AWM and MMHRs. The TAT was then examined to determine the impact of each factor on the MTTR during the repair process. Then MTTR was studied to determine what affect CASS had on the maintainability and sustainability aspects of the repair process.

4. BCM Rates -Internal Measure

If a component is beyond the repair capability of an Intermediate level activity the component is BCMed. BCM is an internal measure of the repair process capability, as well as, the responsiveness of the supply system. There are many reasons for an item to

be BCMed. For example, whenever an IMA repair is not authorized or when the activity is not capable of accomplishing the repair because of a lack of equipment, facilities, technical skills, technical data, or parts, the component is BCMed. BCM will also be used when shop backlog precludes repair within time limits specified by existing directives. (OPNAVINST 4790.2H) The BCM rate was studied to determine if since the fielding of CASS, if it had an effect on the repair capability of the repair process.

A before and after comparison of the BCM rates was used to determine if there was a significant change in the rate. The data used for this analysis was for the period:

- Before CASS -1 January 1990 to 31 December 1993
- After CASS -1 January 1994 to 31 December 1997

This analysis was based on all five components that were repaired in the radar shop. The data was obtained by using the 3M database provided by NAVAIR. All BCMs were totaled for each period. This number was then used to determine the total BCM rate percentage for each period. The following formula was used for these calculations:

$$\text{Percent BCM} = \frac{\#\ \text{BCM}}{\text{Total}\ \#\ \text{Repairs}}$$

It is important to stipulate, the fact that an item is BCM does not always mean the work center could not repair the component. For this system, AIMD Lemoore had full maintenance capability on each component; each system component that entered the repair cycle could be restored. However, some BCM actions are directed by higher

authority whenever they deem it is not cost effective to repair an item. These decisions lead to higher BCM rates that are not strictly process related and result in an unfair bias against the AIMD repair cycle capability.

D. ANALSYIS STRATEGY

1. Turnaround Time

The objective of this thesis was to perform a before and after comparison of MTBF and MTTR of the I-level repair process. A sample from an organizational squadron radar system data was analyzed during the 4-year period before and 4-year period after the fielding of CASS. This collection of data yielded a total of 1133 pre-CASS failures and 1384 post-CASS failure to be analyzed. The flight hour data provided by NAVAIR required to measure MTBF and MTTR were grouped by quarter. To facilitate our analysis, these failures were also assembled by quarter.

2. Comparative Analysis

A graphical approach was used for initial before and after comparison between the MTBF and MTTR results. The box-plot provides a quick impression of the distribution of the data by graphically showing the central location and scatter/dispersion of the data. Figures 1 and 2 show side-by-side box-plots and provides a graphical description of the box-plot format:

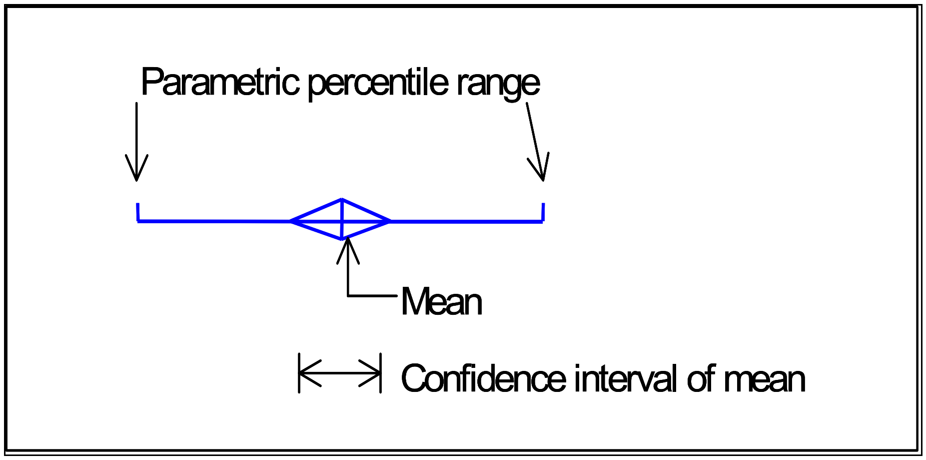

Figure 1 Parametric Statistics Legend

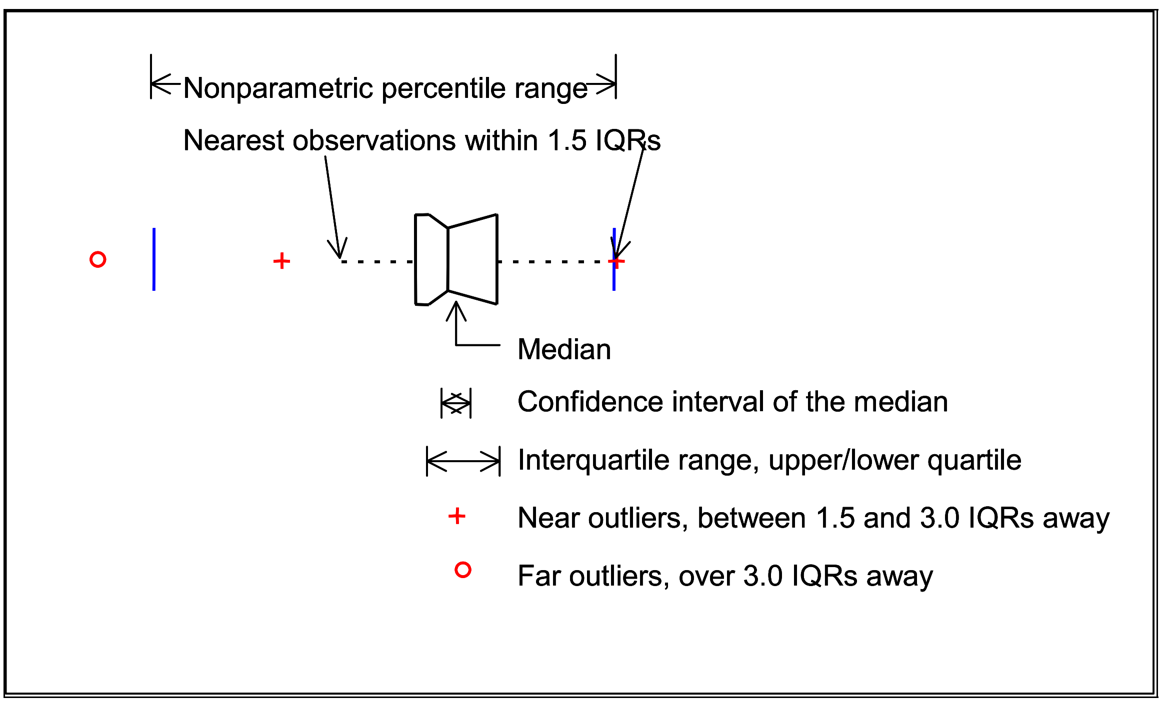

Figure 2 Non-parametric Statistics Legend

The notched box shows non-parametric statistics of the median, lower and upper quartiles, and confidence interval around the median. The box shows the Inter-Quartile

Range (IQR), which contains the central 50 percent of the sample distribution. The vertical bar and notch, within the box, show the median and 95 percent confidence interval of the median respectively.

The dotted line connects the nearest observations within 1.5 (IQRs) of the lower and upper quartiles. Crosses (+) and circles (o) indicate possible outliers. Circles indicate near outlier observations of more than 1.5 IQRs from the quartiles. Crosses indicate far outlier observations of more than 3.0 IQRs from the quartiles. The bracket beside the boxes shows parametric statistics of the mean, confidence interval around the mean and the 95 percentile range.

In addition to graphical analysis, a descriptive statistics of the maximum value, minimum value, range, median, inter-quartile range, mean, and standard deviation were calculated for each factor. A sample of eight years of data was collected, resulting in the analysis of 2517 failures. Theses failures were grouped by quarter, providing 16 data points for each period.

III. ANALYSIS OF THE RESULTS

The data tables presented in Appendix F were evaluated using graphical and numerical summaries to interpret the results that are contained in the following paragraphs. Side-by-side box plots and descriptive summary statistics of both the pre-CASS and post-CASS periods were used to analyze the I-level repair process.

A. MTBF

1. Graphical Analysis

The F/A-18 Radar system consists of five serially connected components. A failure of any component results in failure for the entire system. Thus, the component with the smallest reliability has the biggest effect on the system's reliability. The MTBF of these components were measured before and after to determine what affect CASS had on the ability to properly diagnose and restore these five components. The combined failure distribution determines system operational availability.

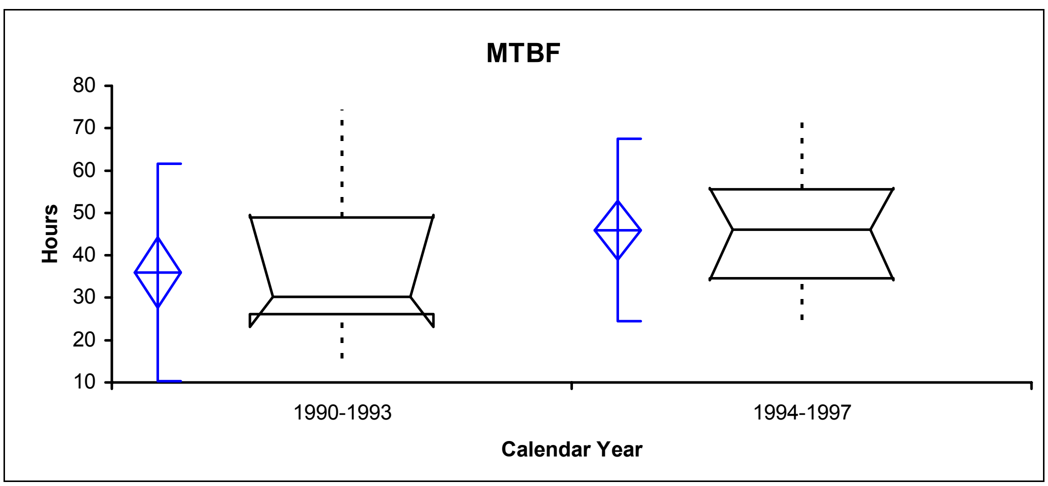

Figure 3 Side-by-Side Box Plots of MTBF

Figure 3, shows that Quartile 1 from the period 1994-1997 values were above the median value from the period of 1990-1993. Therefore, 75% of the means were higher in the after period than the before period. Also, the before period showed a more pronounce difference in mean. Table 1 shows the data spread for the pre-CASS and post-CASS period. The post-CASS period results were less variable than the first; pre-CASS standard deviation was 15.55 and post-CASS standard deviation was 13.07. During the post-CASS period, these results are indicative of a more stable process, which allows managers to make better support decision.

RADAR SYSTEM	MAX VALUE	MIN VALUE	RANGE	MEDIAN	IQR	MEAN	STD DEV
MTBF **PRE-CASS**	74.43	15.72	58.71	30.18	22.73	35.84	15.55
MTBF **POST-CASS**	72.38	24.10	47.67	46.07	20.99	45.95	13.07

Table 1 Descriptive Statistics for MTBF

2. Radar System Components

In addition to the system graphical analysis, descriptive statistics of the mean and standard deviation were also calculated for each component. Table 2 provides a summary of the pre-CASS and post-CASS descriptive statistics for the radar system components MTBF data:

SYSTEM COMPONENTS	742G100	742G200	742G300	742G400	742G600
MTBF PRE-CASS	145.92	147.39	550.15	158.54	341.25
MTBF POST-CASS	188.38	200.33	349.57	310.54	277.70
STD DEV PRE-CASS	124.42	52.35	423.68	90.78	207.44
STD DEV PRE-CASS	80.47	115.67	146.91	157.16	166.77

Table 2 Descriptive Statistics for Radar System Components

Table 2, shows slight decreases in MTBF in 742G300 and 742G600, while 742G100, 742G200 and 742G400 experienced significant increases in MTBF. The largest mean difference change was for the post-CASS measure of the 742G400 component with a mean difference of 151.919 (95.87% improvement). However, the key to reliability improvements in this system can be explained by the changes in the components with the lowest reliability. This increase in system MTBF is due to the improvements in both 742G100 and 742G200 (30% and 36% respectively). As a result, the reliability for the system during the post-CASS period mean improvement was 10.11 (28%).

B. MTTR

1. Graphical Analysis

Its layout, operational procedures and the environment determine the performance of a process. All time dependent repair process measures will exhibit some variability. Variability emerges because of the inconsistency between the actual and the expected

performance. This descriptive analysis of the pre-CASS and post-CASS repair process performance involved summarizing the distribution in terms of its mean, which is defined as the expected value and the standard deviation, which measures the spread of the distribution around the mean.

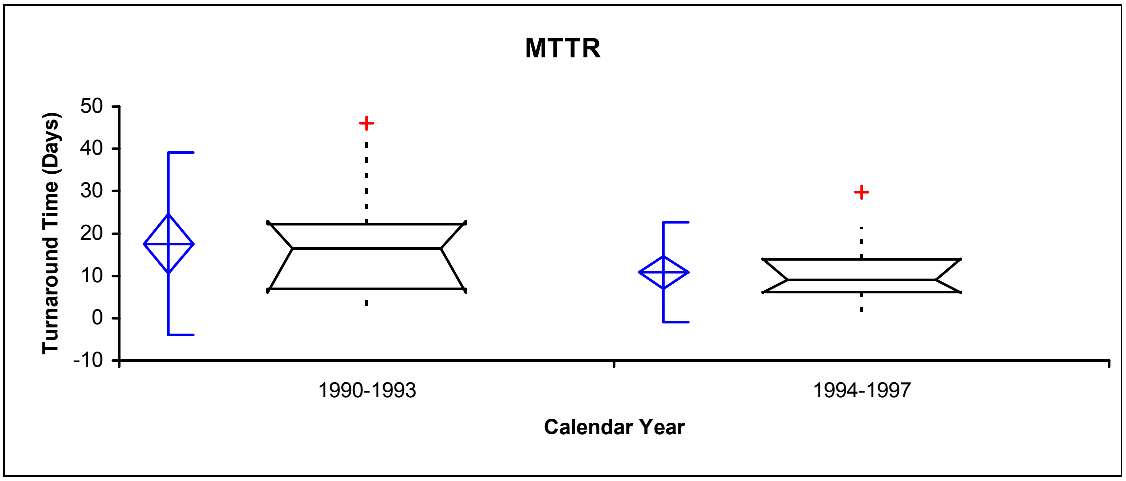

Figure 4 Side-by-Side Box Plots of MTTR

The post-CASS portion of Figure 4 shows a reduction in mean turnaround days as compared to the pre-CASS portion. The most revealing information gained is that 75% of the values in the after period 1994-1997 are less than Quartile 1 in pre-CASS period from 1990-1993. Also, the range of values in the post-CASS period is 14.695 (51.59% improvement) less days than the pre-CASS period. The difference between maximum values in the pre-CASS and post-CASS period was 16.26 (35% decrease)

.

PERIOD	MAX VALUE	MIN VALUE	RANGE	MEDIAN	IQR	MEAN	STD DEV
MTTR **PRE-CASS**	46.06	3.03	43.03	16.37	15.26	17.55	10.79
MTTR **POST-CASS**	29.77	1.43	28.34	9.10	7.79	10.79	7.17

Table 3 Descriptive Statistics for MTTR

Table 3 provides a summary of the pre-CASS and post-CASS descriptive statistics for the MTTR results. It shows the standard deviation in the post-CASS period decreased by 3.62 (50.49% improvement), which indicates a more predicable output. The fastest that a component was processed in the pre-CASS period was 3.03 versus a 1.43 producing an astonishing 111.88% improvement.

Though, the post-CASS measures included 22% more failures for evaluation, the repair cycle turnaround time for this period still showed a mean difference decrease of 6.75 (62.65 % improvement) mean days. This decrease in mean time to repair not only results in a reduction in the number of weapons systems and components in the repair pipeline, but it also reduces the number of spares required to maintain the system. Thus, more weapon systems are available to the organizational level and less capital is required for spares. This money can be used to improve other logistical shortfalls, which translates to higher readiness, as well as, additional savings in inventory cost.

C. REPAIR PROCESS INTERNAL FACTORS

Ao is the constant metric used in Naval Aviation in evaluating the availability or operational readiness of a squadron. Operational availability is defined as the probability that a weapon system, when used under stated conditions in an actual operational environment, will operate satisfactorily when called upon. Thus, any reduction in process cycle time or its variability will increase Ao. The turnaround days for the repair cycle were dependent on the MMHRS, EMT, and AWM.

1. Graphical Analysis MMHRS

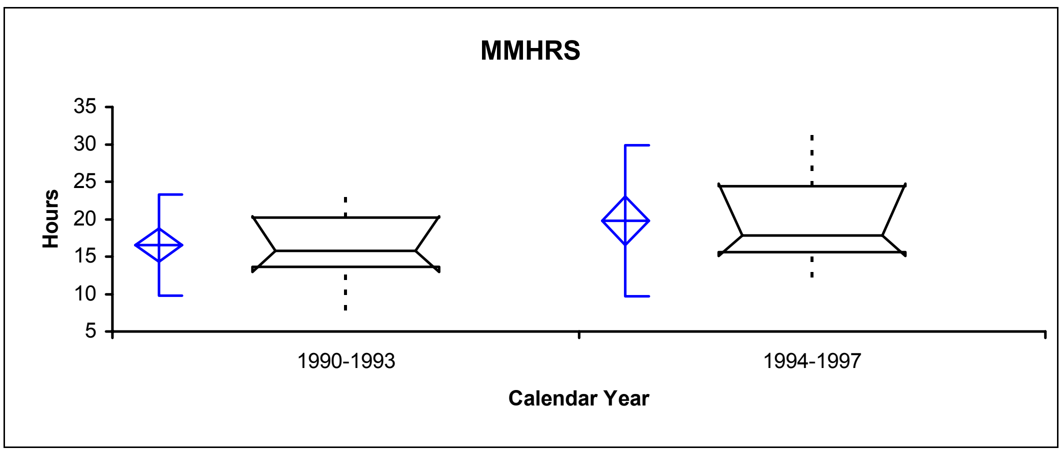

Figure 5 Side-by-Side Box Plots of MMHRS

Figure 5 shows that each of the MMHRS summary statistics values for the post-CASS period was moderately higher than the first pre-CASS period. However, these results alone, do not prove that the before period was more efficient. Instead, these values indicate component degradation over time, which requires extensive troubleshooting, or this change could be the result of improved work center

documentation or simply explained by the methods in which man-hours are collected and recorded in the NALCOMIS database.

PERIOD	MAX VALUE	MIN VALUE	RANGE	MEDIAN	IQR	MEAN	STD DEV
MMHRS PRE-CASS	23.11	7.86	15.25	15.79	6.59	16.54	4.11
MMHRS POST-CASS	32.46	12.25	20.21	17.85	8.78	19.77	6.12

Table 4 Descriptive Statistics for MMHRS

Table 4 shows the median value for the post-CASS exceeds the median value for the pre-CASS period by 2.06 (13.04%). The minimum value for the post-CASS was 12.25 and 7.86 for the pre-CASS resulting in a change 4.39 mean hours (59.67% additional requirement). These results are not surprising because as weapon systems age, more man-hours will be required due to the increased complexity of the task.

2. Graphical Analysis EMT

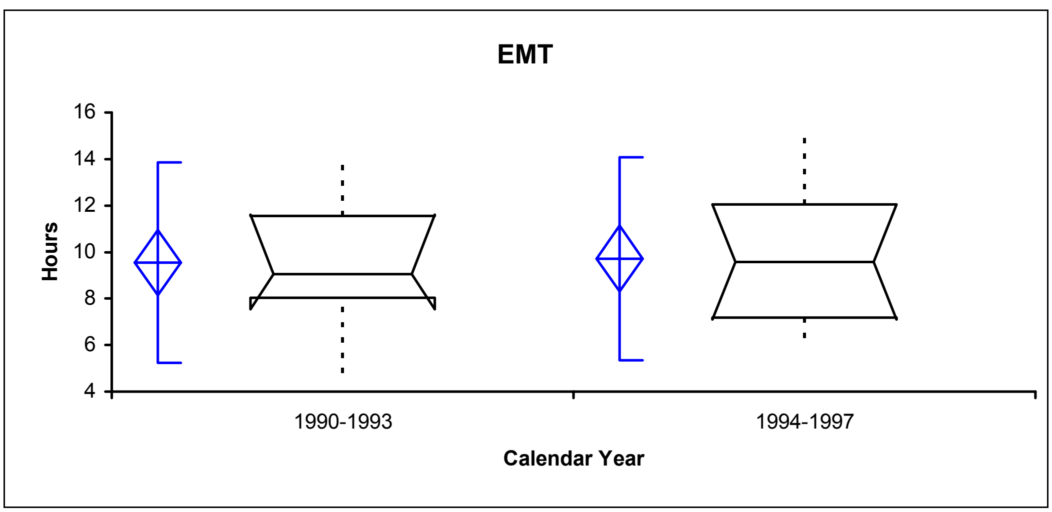

Figure 6 Side-by-Side Box Plots of EMT

Of the factors effecting MTTR, the characteristics exhibited by EMT were the most stable in this repair process. MTTR, the most critical measure in this study because of the direct correlation to work centers' realized output rate. Figure 6 shows a steady state for both the pre-CASS and post-CASS periods.

PERIOD	MAX VALUE	MIN VALUE	RANGE	MEDIAN	IQR	MEAN	STD DEV
EMT **PRE-CASS**	14.067	4.809	9.258	9.050	3.500	9.55	2.62
EMT **POST-CASS**	15.097	6.295	8.802	9.569	4.846	9.71	2.65

Table 5 Descriptive Statistics for EMT

The values in Table 5 show that this process factor is in a stable state of statistical equilibrium. The difference in the mean and standard deviation values were statistically insignificant for both periods. However, given the improvements to turnaround time and the fielding of CASS, these results were unexpected. We expected significant improvements during the post-period. During the post-CASS period, the work center was equipped with a bench that had better self-test abilities and maintainability features that should reduce EMT. With CASS, less repair time is loss due to actual program run time, and, additional time is saved by not troubleshooting the station as often during the test and repair process as with the RSTS. The results gained here illustrate the importance of making corresponding changes to each logistical element. Without improvements in supply support, appropriate sparing levels, and depot level support, the repair process cannot achieve its full potential; any gains will be marginalized. These results can best be attributed to process design and its inherent inefficiency.

3. Graphical Analysis AWM

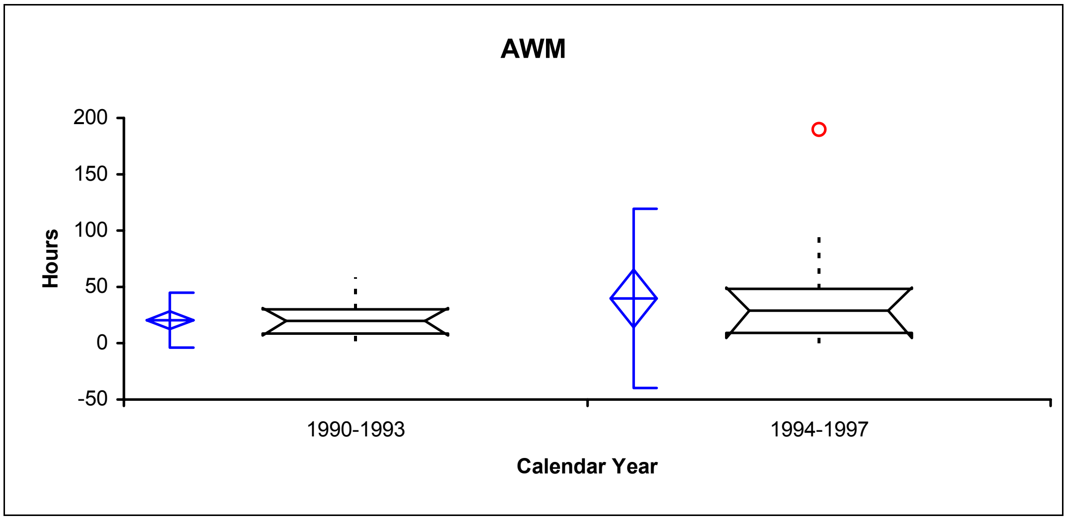

Figure 7 Side-by-Side Box Plots of AWM

Figure 7 shows a significant increase in waiting time. Quartile 1 of the post-CASS period is higher than Quartile 3 of the pre-CASS period, which means that at least 75% of the values in the post periods are higher. The maximum value for the pre-CASS period was 58.32 and the values for the post-CASS periods 189.76, an increase of more than 225.38% of backlog time. However, the minimum delay time for the post-CASS period was .23 while the least value for the pre-CASS period was 1.82, a difference of 1.59 mean hours.

PERIOD	MAX VALUE	MIN VALUE	RANGE	MEDIAN	IQR	MEAN	STD DEV
AWM PRE-CASS	58.32	1.82	56.50	19.68	21.89	20.55	14.90
AWM POST-CASS	189.76	0.23	89.76	29.06	39.27	39.79	48.42

Table 6 Descriptive Statistics for AWM

Table 6 shows the numerical results. The pre-CASS mean AWM hours were 20.55 and the post-CASS periods values were 39.79 hours; a negative difference of 19.24 (93% unfavorable change). This factor shows significant levels of variability. Whether this is work center induced (using one component as a spare parts unit which produces extreme out-layers in the data spread), or process driven (down bench). It was difficult to isolate the actual cause of this increase in wait time from the parameters analyzed in this study. However, external factors such as increased operational tempo at the organizational level coupled with a slow depot level turn around time can explain some of this variability in the post-CASS process wait time.

D. ADDITIONAL PROCESS MEASURE

A pre-CASS and post-CASS comparison was made of the squadron's "Y" code rate to determine if the supported squadron received fewer defective components. The pre-CASS for "Y" codes count was 66 out of 1133 (5.8%) components repaired. The post-CASS count for "Y" was 80 out of 1348 (5.8%)component repaired.

Also, a BCM rate comparison was done to determine whether the work center ability to make repairs had changed. The pre-CASS count for BCMs was 11 out of 1133 (5.8%) components repaired. The post-CASS count was 48 out of 1348 (3.6%) components repaired. The count for each measure was lower than expected; this can be explained by incomplete or inaccurate data fields. However, with the data provided, for the purpose of this study the results of these additional external and internal process measures proved to be negligible.

VI. CONCLUSIONS AND RECOMMENDATIONS

This thesis examined the impact CASS has had on the I-level repair process over time. AIMD Lemoore was selected to test this analytical approach that used box plots and descriptive statistics to perform a before/after comparison of the repair process. The raw data collected from NAVAIR provided enough material for conclusions to be drawn and uncovered areas of interest that warrant further research.

The implementation of CASS improved the mean difference of the inherent reliability of the radar system and reduced the mean turnaround time. The pre-CASS mean time between failure was 35.84 hours with a standard deviation of 15.55 hours. The pre-CASS mean time to repair was 17.55 days with a standard deviation of 10.79 days. The post-CASS mean time between failure was 45.95 hours with a standard deviation of 13.07 hours. The post-CASS mean time to repair was 10.79 days with a standard deviation of 7.17 days. This mean difference improvement represents a significant change in MTBF (10.11 hours) and MTTR (6.76 days). Additionally, the overall effect on the maintenance process is immeasurable because these improvements reduced cycle time which decreases the cannibalization rate, reduced spare inventory levels required and increased operational availability.

However, this study of the repair process also highlighted major areas of concern in the area of data collection and process performance variability. This creates major concerns when future acquisitions/modifications decisions are only based on measurement of the mean and not the total data spread.

A. CONCLUSIONS

The following are specific conclusions drawn from this study:

1. We must collect better data to allow managers to scrutinize the process in detail.

Process controls should involve tracking variability between the projected and actual MTBF and MTTR. Therefore, we must collect accurate information about critical performance measures over time (such as MTBF and MTTR) and take corrective actions based on observed variability in real time. Furthermore, manager must set control limits of acceptable variability in key performance measures, monitor actual performance, and correct any abnormal variability.

2. Process variability matters; logisticians must make a concerted effort to measure it.

It is no longer prudent just to perform a mere before and after comparison of the mean; repair process variability, if remained unchecked, leads to unsatisfied customer, disenchanted sailors and a process can be downgraded to an unstable state. The same attention that has been paid to analyzing the mean failure distribution needs to be also applied to process variability.

3. Finally, we must establish better communication between user activities and the Program managers.

Process related problems that adversely impact maintainability or supportability must be addressed in real time to facilitate future process/program related decisions.

These concerns must be communicated at all levels. Communication by accurately documenting failure data in the NALCOMIS database is the most powerful voice for the maintainers. A quantifiable tool that can assist the local activities in drawing attention to their problems early on.

B. RECOMMENDATIONS

The following are specific recommendation drawn from this study:

1. Modify our data systems collection requirements to allow for complete analysis of root failure causes.

In order to better understand the impact of any process changes, our current data reporting system must be modified to allow for individual component tracking and collection of the root causes of failures for the total life of a component. All pertinent records required to measure mean time between failure and mean to repair for a repairable system should be maintained and verified prior to any system upgrades or major modifications.

2. We need methods for measuring, analyzing and controlling variability in actual performance over time.

The same attention and resources that has been devoted to analyzing the mean failure distribution needs to also be applied to investigating the root causes of process variability. Not only does the averages matter; for logisticians at all levels, knowing the process performance variability is just as important for making program saving/changing decisions. Therefore, we must understand exactly what the process can produce and what

it actually produces. Then we can institute methods for measuring, analyzing and controlling variability in actual performance over time.

3. Successful Communication is crucial in optimizing maintainability and supportability aspects of a weapon system.

We should continue to expedite the fielding of Optimized NACOMIS because it provides aviation maintenance and material management with timely, accurate, and complete information. In addition, we need to devise procedures that monitors and correct the accuracy of the data provided from various activities in real time.

C. AREAS FOR FURTHER RESEARCH

This research did not address cost aspect of fielding CASS. A study is suggested that will look at the cost implications of fielding CASS. Additionally, a study is required that uses historical data within this framework of the design to evaluate a different intermediate maintenance level activity or weapon system to determine whether this approach is useful for predicting/making future system changes. Finally, and perhaps of paramount importance a further study that addresses what were/are the current system capability tradeoffs is vital; are we limiting our technological advances by designing radar systems (or any system) to be within the test/repair capability of CASS?

APPENDIX A. NAVAL AVIATION MAINTENANCE AND SUPPLY

The objective of the Naval Aviation Maintenance Program (NAMP) is to support aviation readiness and safety standards established by CNO. This is realized by optimizing the use of manpower, material, facilities and financial resources. The NAMP provides for the maintenance, manufacture and calibration of aeronautical equipment and material at the level of maintenance, which ensures optimum use of resources. It also, provides for the collection, analysis, and use of pertinent data to continuously improve material readiness and safety at the least possible cost. (OPNAV 4790.2H)

The performance capability of a weapon system is dependent upon its availability. For the purposes of calculating Operational Availability (Ao), quantitative parameters of reliability and maintainability are used, as is supportability. Ao represents the expected percentage of time that a weapon system will be ready to perform in an operating environment when called upon at any in time. (OPNAVINST 3000.12)

A. INTEGRATED LOGISTIC SUPPORT PLAN

During the development of the logistics plan for a new aircraft system, the first Integrated Logistic Support steps are the Level of Repair Analysis (LORA) and the Logistics Support Analysis (LSA). These analyses form the basis of the Maintenance Plan that serves the system throughout its life cycle. The Integrated Logistics Support Plan, developed by NAVAIR, is designed to support the Maintenance Plan to provide specific guidance on each logistic element. The ILS is the basic system for bringing together the essential actions carried out by various organizations into a coordinated and

planned structure to ensure that a newly introduced weapon system would be adequately supported. (MN4470, Eaton)

1. Level of Repair Analysis

The Level of Repair Analysis (LORA) considers each system in the aircraft and creates estimates of the most cost-effective ways of supporting that system. Early in the acquisition process, the LORA serves to resolve supportability and maintainability problems. It delineate the maintenance level at which components will be removed, replaced, fault isolate, repaired or condemned. Also, the LORA determines whether an items in the system will be fault-isolated and repaired strictly at the I-Level or be totally repaired at the depot level. This decision plays a major role in the purchase and fielding of test equipment, as well as, the quantity of spares required to adequately support O-level squadrons. (MN4470, Eaton)

2. Logistic Support Analysis and Support Elements

The LORA is an analytical tool, the first-step in making vital logistics decisions, however, it does not consider design peculiarities of the equipment. The first design-related logistics review take place in the LSA. At the conclusion of this process, the logistic support community has defined the final maintenance concept for the system, as well as, the individual components. Since the maintenance concept and ILSP are interdependent, a change in either will result in a corresponding change to the other. Therefore, the logistical support elements must be addressed in the same manner in each

plan because a change in one may result in an unintended change to the other. The major logistical elements include (MN4470, Eaton):

- Maintenance planning
- Manpower and personnel
- Supply support
- Support equipment
- Technical data
- Training and support
- Computer resources support
- Facilities
- Design interface
- Configuration management
- Spares
- Reliability

The manner and extent to which these elements are coordinated determines aircraft readiness rates. The maintenance process cannot proceed in an orderly manner unless this is accomplished. Of these elements, our focus was the repair process and the impact of its associated process activities on the turnaround time of the AIMD repair cycle. (MN4470, Eaton)

B. MAINTENANCE PLAN

While the Integrated Logistic Support Plan is an overall logistics planning document, the maintenance plan is a specific "how to" document for each system in the aircraft. The maintenance plan delineates the repairable component and maintenance requirements for each system. It also, identifies the maintenance level or activity authorized to perform the maintenance action indicated, and estimates the frequency of component failure or repair action. (MN4470, Eaton)

For the logistician, the maintenance plan is used to manage the repair process. Each item is assigned a source, maintenance and recoverability (SM&R) code. This code reflects the line item's unique maintenance plan indicating the manner of acquiring components for the maintenance, operation, rework or overhaul efforts. For the repair process to operate smoothly, it is imperative that each logistical element be linked to the maintenance plan. For example, it would be ineffective to have trained technicians at the I-level if the spare parts were not available. Even if spare parts are in place, support will be inadequate if there is no test equipment to fault-isolate and make repairs. The concept of integrated logistics as it relates to repair processes, demands that all of the logistics elements are provided in appropriate measure at the proper time. (OPNAVINST 4790.2H)

1. Levels of Maintenance

The objective of the NAMP is to improve aviation material readiness and safety standards established by the Chief of Naval Operation's. This goal is realized through the division of maintenance into three levels; organizational, intermediate and depot). These levels facilitate management desires to easily classify maintenance functions and assign maintenance tasks to the appropriate level. (OPNAVINST 4790.2H) The following is a detailed description of the three levels of maintenance.

a. Organizational Maintenance

The primary mission of an O-level maintenance activity is to sustain and maintain aircraft systems in a mission capable status. Personnel assigned to these

activities perform maintenance at the operational site and conduct on-equipment maintenance functions. Maintenance at this level consists of inspections; servicing; troubleshooting; on-equipment corrective and preventative maintenance; incorporating technical directives; and recording keeping. O-level is that of the user/operator, usually aircraft squadron. Mission success depends on the support provided by both the local Intermediate Maintenance Departments, as well as, the Depot level. (OPNAVINST 4790.2H)

b. Intermediate Maintenance

The I-level of maintenance is represented by Aircraft Intermediate Maintenance Departments (AIMDs) at Naval Air Stations and aboard ships. The goal of the I-level maintenance team is to enhance and sustain the readiness of user activities by providing both direct and indirect support of the O-level. At the I-level, direct support function includes: repairing major modules, assemblies, sub-assemblies or piece part to repair components. It also, performs off-equipment calibrations, manufactures parts not available through the normal supply channels, provides technical assistance, and conducts repair at the weapons repairable system (black boxes) and subassembly level. (OPNAVINST 4790.2H) The study focused on the I-level repair process output.

c. Depot Maintenance

The industrial capability that stands beyond the O-level and I-level of maintenance is the depot repair level. Maintenance at this level involves the complete

repair and/or overhaul of components. Depot maintenance is the key readiness driver, particularly in an aging fleet and is the source for:

- Life-cycle support
- Major inspections
- Special structural inspections
- In-service/sustaining engineering
- Modifications
- Service life extensions
- Postproduction source

The Depot level is the most sophisticated and final level of repair for aircraft components. If the depot cannot restore a component, it goes to disposal and the procurement process for replacement is initiated. (MN4470, Eaton)

C. AIRCRAFT INTERMEDIATE MAINTENANCE DEPARTMENTS

The goal of an AIMD is to support readiness of user activities by providing high quality and timely direct and indirect support. Direct support is work performed on repairable parts and equipment received from squadrons, such as, testing and checking of avionics equipment, non-destructive inspections (NDI), and the manufacturing of items that are not available through the supply process. The majority of the AIMD's workload is generated from indirect support requirements, such as, restoring defective repairable components, which are then placed in the local air station inventory pool.

The I-level repair process output is the Supply Departments' primary source for repairable components. The I-level is the repair arm for the local Supply Department; they fill shelves. Those components or assemblies that cannot be repaired, or are not authorized for repair at the I-level are either condemned or labeled "Beyond the

capability of maintenance", (BCM) and forwarded to depot level. (OPNAVINST 4790.2H)

1. Funding Allocation

The AIMDs receive two major types of funds from the local air station; Aviation Fleet Maintenance (AFM) fund, and Aviation Depot Repairable (AVDLR) fund. AFM funds are used to purchase consumables parts and ADVLR funds are used to purchase repairable components for repairable items. Funds are allocated to the Type Commander based on the Type/Series/Model (TMS) of aircraft under their control. The Type Commander apportions theses funds to air stations based on the type and number of aircraft assigned in the local area supported by IMA, as well as the projected operational tempo.

2. Spares Management

The Aviation Consolidated Allowance List (AVCAL) and Shore based Consolidated Allowance List (SHORCAL) are developed by the Aviation Supply Office (ASO). The AVCALs are combat driven, while the SHORCALs are based on a thirty-day peacetime scenario for CONUS activities. ASO constructs SHORCAL/AVCAL fixed allowances using the Aviation Maintenance Material Management (3M) Data system. The consolidated allowance list of aeronautical material is tailored to each individual command designed to support for a 90-day period. It states the range and depth allowance for repairable items, subassemblies and repair parts that are required for support of assigned aircraft, engines and end items of support equipment.

Availability of spares is a key driver of readiness; if not supplied in the appropriate quantity can severely paralyze the repair process. Therefore, spares for a system must meet optimal stock levels. For system components that are repaired at the I-level, the BCM rate will directly affect sparing requirements needed to maintain an acceptable level of operational availability. The average number of spares required to mitigate the impact of attritions is directly related to the BCM rate. An increase in maintenance capability is crucial to maintainability factors. In view of that, any improvements in equipment reliability or maintenance process that reduce turnaround time or the BCM rates can reduce the quantity of system spares required to achieve adequate protection against empty shelves or holes in the aircraft. (OPNAV 4790.2H)

3. Maintenance Data System

The MDS was developed as an integral part of the Navy's 3M System and provides data input to the NAMP. The collection of aviation 3-M data at user activities provides a database of aviation maintenance actions for future decision-making. The MDS is a management information system designed to provide statistical data for use at all management levels relative to:

- Equipment maintainability and reliability
- Equipment configuration, including alteration and TD status
- Equipment mission capability and utilization
- Material usage
- Material non-availability
- Maintenance and material processing times
- Weapon system and maintenance material costing

The MDS provides a valuable tool for use by maintenance management. The key to an effective MDS is the Work Center Supervisor. A product from MDS is only as good as the input information. The input is used to provide management products for the highest levels of Navy management. (OPNAV 4790.2H)

a. Data Accuracy

Accurate documentation is a continuous concern throughout the MDS process. Each uncorrected erroneous document results in a loss of effectiveness of the submitted data, as well as, reduces the overall dependency on the system. For that reason, at the user level, work center supervisor must assure absolute accuracy. Recurring documentation errors must be recognized early and any discrepancy noted must be corrected immediately. The importance of accurate and complete data cannot be overemphasized especially when Navy wide usage of this data is considered. (OPNAVINST 4790.2H) In fact, higher-level Navy managers use this data daily to:

- Analyze high system failures and high man-hour consumers by specific weapon system.
- Identify desirable product improvements.
- Analyze inspection requirements as a basis for adjusting inspection criteria and intervals.
- Adjust component scheduled removal intervals.
- Improve I-level repair capabilities.
- Identify failed items under warranty.
- Establish realistic manning factors.
- Determine and justify the need for modifications and engineering changes.
- Establish equipment reliability factors.
- Determine tooling and equipment requirements.
- Predict probable failures through trend analysis.
- Determine the status of compliance with mission readiness type TDs

4. Repairable Component Management

To effectively manage repairable systems, both the reliability and maintainability must be considered jointly; combined they determine availability. In this resource-constrained environment, repair process output is a major source of supply for aviation components. The timely and efficient repair is the key to repairable availability, and it is the effectiveness of this process that drives aircraft readiness. It is imperative for the logistician to understand both the maintenance capabilities and support requirement for the system. Table 1, shows the relationship between maintenance and availability when the reliability changes:

Reliability	Maintenance	Availability
Constant	Increases	Decreases
Constant	Decreases	Increases
Increases	Constant	Increases
Decreases	Constant	Decreases

Table 7 Reliability Matrix

APPENDIX B. PROCESS VIEW

A. OVERVIEW

For any organization, a process is the transformation of inputs into outputs. To adequately evaluate and improve the performance of a process, managers must look internally and externally to scrutinize the input-output transformation and measure it in quantifiable terms. The effectiveness of a process is measured by current performance and how it correlates to achieving future goals as expressed by the strategic direction of the organization. (Anupindi, 1999) The following is a brief description of the importance of process measures as it applies to this research.

1. The Importance of Process Measurements

Leaders must manage with facts rather than intuition or emotion. By capturing facts in an objective, concrete, and quantifiable manner, process control measurements provide leaders a basis for making program saving/changing decisions. As long as internal measures are used as a basis for process-related decisions and external measures indicates the effectiveness of those decisions, such measures will enable logisticians to satisfy the needs of the fleet. (Anupindi, 1999)

B. INTERMEDIATE LEVEL MAINTENANCE REPAIR PROCESS

Naval Air Station Supply Departments maintains an inventory of Ready For Issue (RFI) repairable aircraft parts to meet the requirements generated by user activities. This inventory is referred to as the rotatable pool. The critical factors in maintaining the

rotatable pool depth and range to meet the requirements of the squadrons are the local IMAs' capability and subsequent turnaround time.

1. Aviation Support Division

The ASD is composed of two main sections: Supply Response Section and Component Control Section. They will issue material or provide status within established time limits. Figure 8, (OPNAV 4790.2H) is a layout of a typical ASD:

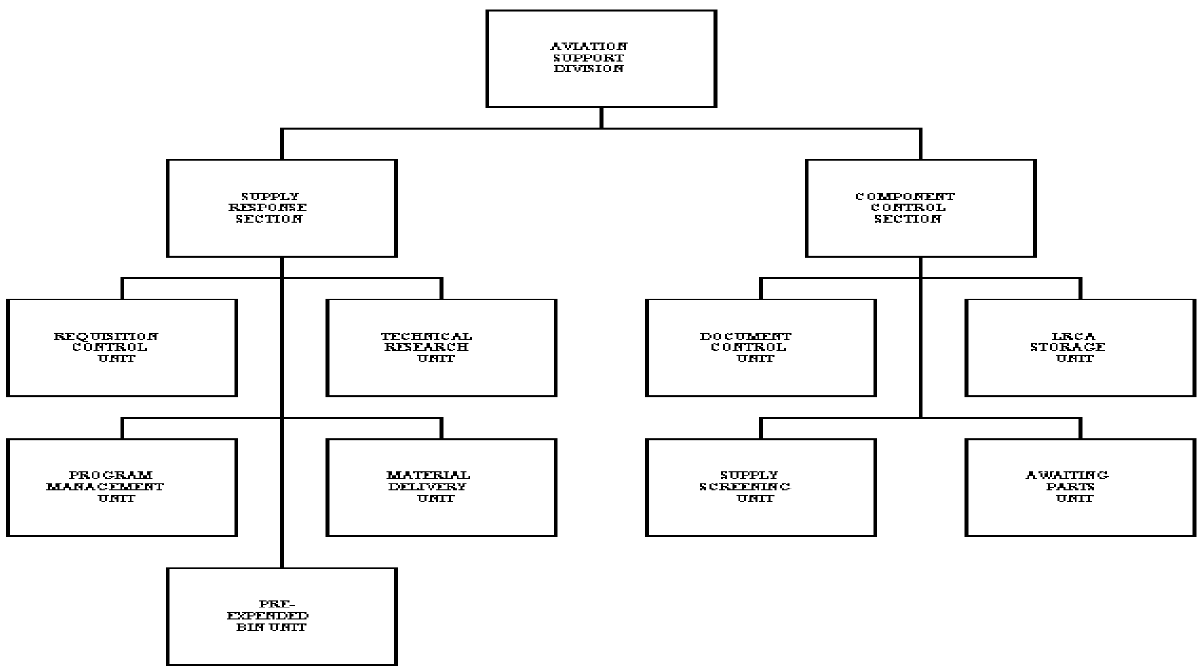

Figure 8 Aviation Support Division

The repair process cycle flow is initiated when a squadron orders a replacement item and turns in a non-RFI item to the supply Department's Aviation Support Division. If available, the ASD will issue the squadron an RFI item from its pool. The ASD will then assign a repair priority to the non-RFI item and pass the part to the Aeronautical

Material Screening Unit. Accompanying the defective part will be a Maintenance Action Form (MAF). This form is used to document the discrepancy and all repair actions made to the component. AMSU screens the component to ensure that the IMA has repair capability and enters all the appropriate data into NALCOMIS. If the IMA has repair capability, the defective component is then forwarded to the appropriate work center to effect repair (OPNAV 4790.2H).

a. Supply Response Standards

Maximum elapsed response times are established for issuing items available in local supply stocks or furnishing requisition status on an automatic basis for not carried and not in stock items. Response time starts when Material Control (O-level or I-level) places a requirement on ASD, time stops when the requested material or status is received at the delivery point. ASD will issue material or provide status within standards listed in Table 8.

ISSUE PRIORITY GROUP	PROCESSING TIME
1	1 HR
2	2 HRS
3	24 HRS

Table 8 ASD Response Times

For the repair cycle, assigning the correct priority is critical. It dictates how fast a component must flow through the repair process and the speed in at which replacement parts are requisitioned[1].

[1] Priority 1 signal expeditious repairs, assigned when there are no replacement items in the pool. Priority 2 is assigned to items that have dropped below a specific depth. Priority 3 is assigned to items that have inventory level within the established depth and range.

2. Avionics Division

The Avionics Division, a part to the local AIMD is divided into two major branches Avionics and PME. Figure 9, (OPNAV 4790.2H) is a layout of the division:

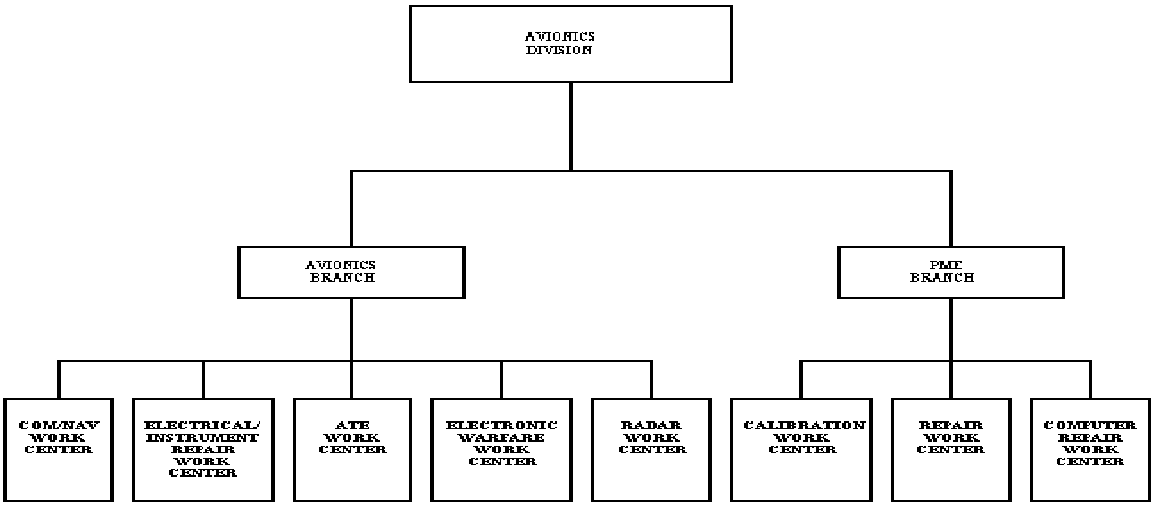

Figure 9 Avionics Division

The work center supervisor receives the component, screens the Maintenance Action Form (MAF), and assigns a worker to the maintenance action. When the worker begins working on the component, the in-work date and time are annotated on the MAF. During the repair process, if the worker determines that replacement parts are required to complete the repair, the worker annotates the required material blocks of the MAF with the required parts. These parts are placed on order through the Supply Department. Once maintenance is completed, the worker marks the MAF as job complete and awaits a Collateral Duty Inspector (CDI) to inspect the work. Once the job is inspected, the Work Center Supervisor reviews the MAF and then notifies AMSU that the component is RFI

and ready to be picked up. The component is then delivered to the Component Control Section (CCS) where it is staged in the rotatable pool for future or immediate use by a squadron.

C. REPAIR CYCLE

The repair process serves to restore the inherent reliability of a component. Repairable systems failure rate (reliability) and repair rate (maintainability) are equally important. A failure distribution describes the average time it takes for a component to fail. While, a repair distribution describes the average time it takes to repair a component. To perform an adequate analysis of the repair process, it is important to understand and consider the interrelation of these distributions. Combined, they determine Ao for a given system. This study measured the average mean time between failure (MTBF), indicates how long a component remains in the operational environment and mean time to repair (MTTR), indicates how long a component is likely to be out of service while under repair.

1. Maintainability

Maintainability is defined as the probability of performing a successful repair action within a given time. It measures the ease and speed with which a system can be restored to operational status after a failure occurs. In maintainability, variable of concern is time. The maintenance down time is the total elapsed time to repair until corrective action is completed. This maintenance time encompasses all factor required to complete the repair action. Reducing this time is the focus of most process managers.

- The time it takes to successfully detect the cause of the failure.
- The time it takes for the preparation for maintenance.
- The time it takes to localize and isolate the failure.
- The time it takes for disassembly.
- The time involved for repair of equipment/removal of faulty item.
- The time it takes for reassembly, align/adjust and verifies that the system is functioning within specifications.

2. Radar Repair Shop

At the I-level, work center 63D which is the radar shop, is a part of the Avionics Division. In 2002, they repair two radar systems, the APG-65 and APG-73 Phase I. The APG-73 Phase II is being introduced to the fleet now, and APG-79 is on target to be in the fleet by FY07.

3. Radar Test Equipment

Currently, work center 63D uses the Radar Station Test Set (RSTS) and the Consolidated Automated Support System, (CASS) to repair radar components. A prime interest of this study is the repair cycle turnaround time since the fielding of CASS, which a computer driven modular, re-configurable, automatic test station capable of providing performance verification and diagnostic fault isolation for electronic components. (Meredith, 1990)

4. Turnaround Time

Turnaround time is the decisive measure of effectiveness both internally and externally for any maintenance repair process. The final output provides a measure of both maintenance and supply; an indicator of how well the elements are working together. For this study of the I-level repair process, we measured AIMD’s TAT, using

EMT, MHRS, and AWM to quantify the output before and after the fielding of CASS at AIMD, NAS Lemoore.

5. Repair Cycle Process Data Generation

The Maintenance Data System incorporates four distinct but interrelated subsystems:

- Maintenance Data Reporting (MDR)
- Subsystem Capability Impact Reporting (SCIR)
- Material Reporting (MR)
- Utilization Reporting.

The MDR was designed so that each maintenance action job narrative description entered on a standard source document was converted to coded information. These documents are collected and machine processed daily to produce reports. These reports enable maintenance managers to track the nature, quantity, and quality of aviation maintenance work. The focus of this study is the I-level repair processes, of the 13 reports available, the MDR-9; repair cycle data report is relevant. The MDR-9 is a detailed list, showing the number of days of turnaround time and the elements that compose the turnaround time for each repairable component processed through the I-level.

APPENDIX C. AN/APG-65 RADAR SYSTEM

Work Unit Code	Nomenclature
742G100	F/A- 18 Radar Transmitter
742G200	F/A- 18 Radar Receiver
742G300	F/A- 18 Radar Processor
742G400	F/A- 18 Computer Power Supply
742G600	F/A- 18 Radar Antenna

Table 9 Radar System

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APPENDIX D. TEST EQUIPMENT

A. TEST EQUIPMENT

Currently, Work Center 63D uses both Radar Station Test Set and Consolidated Automated Support System. A prime interest of this study is the mean time to repair since the fielding of CASS. However, a brief background is relevant to explain significance of this change in test equipment.[2] Today, CASS is in use throughout the Navy both afloat and ashore; at Navy AIMDs and Depots, at USMC, aboard CVs and L-Class ships, as well as, other sites. Figure 10, is an example of a CASS workstation:

Figure 10 CASS Work Station

The Marcy group study team identified seven problems with automatic testing;

[2] **The Consolidated Automated Support System (CASS) is the Navy's standard Automatic Test Equipment for electronics and avionics related equipment.**

- Proliferation of Automatic Testers
- Test program Set Deficiencies
- Lengthy Periods of Test
- ATE/End-item Interface/Compatibility
- ATE Capability Limitations
- ATE Maintainability
- Spares

CASS was developed in response to the Marcy findings. The $1.2 Billion CASS program was formally initiated in 1982. CASS stations were first ordered in 1990 and CASS entered the fleet in 1994. Now that CASS is in wide use throughout the Navy, most of the original design objective have been achieved to satisfy the problems cited above, and to lower the cost of ownership for our aviation electronics systems. Table 10 shows how logistics costs are reportedly being significantly reduced as CASS replaces the legacy testers in the fleet (PMA 260, website):

	Current 25 Legacy Testers	**CASS**
NECs	32	2
Tech Pub	624	4 disks
Personnel	105	54
Space	2700 ft2	1900 ft2
ATE Spares	30,000	3800

Table 10 Logistical Impact of CASS

APPENDIX E. PROCESS MEASURES

A. I-LEVEL REPAIR CYCLE

1. Turnaround Time MDR-9

The repair cycle time begins when a failed component enters the repair process once it is received and screened by AMSU. The time between actual removal of the component and its turn in to the AMSU of the IMA is processing time. The time between receipt of the component by AMSU and induction into a work center for repair is scheduling time. Repair time, is the time between induction of the component into a work center and completion of the RFI/BCM action, less any awaiting parts time, that is, the actual time devoted to repair. The time during which the component was not being worked on while awaiting repair parts not available locally is Awaiting Parts time. (OPNAV 4790.2H)

The total time between the time period that work is started on the component and completion of the RFI/BCM, that is, the sum of repair time is in work time (EMT). IMA TAT, is the total time required to complete the maintenance action within the IMA, this is the sum of scheduling time and in work time. Finally, total TAT, is the total time required to complete the maintenance actions, from initial removal to final RFI or BCM determination. This information is entered into Naval Aviation Logistic Command Information System (NALCOMIS), which is reported up-line; form the basis for MDR-9 data. Figure 11 shows a representation of the work center flow. (OPNAV 4790.2H)

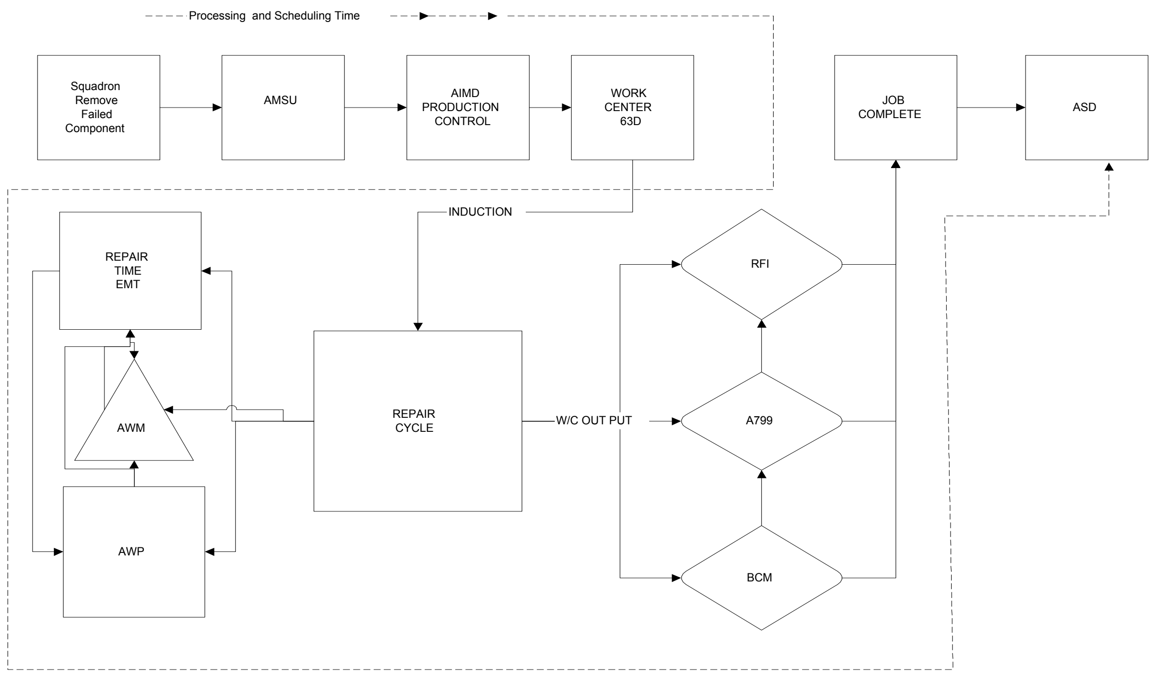

Figure 11 Work Center 63D Work Flow

a. Beyond Capability of Maintenance

BCM is an internal measure of the repair process capability, as well as, the responsiveness of the supply system. A term/code used by IMAs when repair is not authorized at that level or when an activity is not capable of accomplishing the repair because of a lack of equipment, facilities, technical skills, technical data, or parts. BCM will also be used when shop backlog precludes repair within time limits specified by existing directives. (OPNAVINST 4790.2H) The following is a list of BCM codes used at an IMA:

- BCM 1 - Repair Not Authorized
- BCM 2 - Lack of Equipment, Tools, or Facilities
- BCM 3 - Lack of Technical Skills

- BCM 4 - Lack of Parts
- BCM 5 - Fails Check and Test
- BCM 6 - Lack of Technical Data
- BCM 7 - Beyond Authorized Repair Depth
- BCM 8 - Administrative
- BCM 9 - Condemned

b. Awaiting Parts

AWP is an internal process measure that quantifies the supply aspect of the repair process. This condition exists when materials required to complete a maintenance action are not available on station/ship. AWP is that time when no work can be performed on the item being repaired due to a lack of ordered parts. (OPNAVINST 4790.2H)

- WB-In Transit From AWP Locker
- WP-AWP In Shop
- WQ-AWP In AWP Locker
- WS-AWP Work Stoppage
- WT-In Transit to AWP Locker

c. Awaiting Maintenance

AWM is an internal measure of the repair process provides a direct measure for test bench availability. This is the time when an aircraft/component is non-mission or partial capable maintenance and no maintenance is being performed on the systems causing the NMCM or PMCM status. (OPNAVINST 4790.2H)

- M1. Awaiting or undergoing depot repair
- M2. Support equipment, hangar, hangar deck spaces, or facilities

- M3. Backlog, workload is in excess of work center capability
- M4. Off-shift hour
- M5. Other
- M6. Awaiting AIMD maintenance
- M7. Flight operations/operational utilization
- M8. Awaiting other shops or maintenance actions

d. Maintenance Man-Hours

MMHRS is an internal measure of the repair process that can potentially signal long-term concerns. This is the total number of accumulated direct labor hours expended in performing a maintenance action. Direct maintenance man-hours are man-hours expended by assigned personnel to complete the work described on the source document. This includes the functions of preparation, inspection, disassembly, adjustment, fault correction, replacement or reassembly of parts, and calibration/tests required in restoring the item to a serviceable status. (OPNAVINST 4790.2H)

e. Elapsed Maintenance Time

EMT is the most significant process measure especially as it relates to this study. For the purposes of MDR, EMT is defined as the actual clock time that maintenance was performed on a job. Although the EMT is directly related to job man-hours, it is not to be confused with total man-hours required to complete a job. (OPNAVINST 4790.2H) For this study of the I-level repair process, we will measure AIMD's TAT, using EMT, MHRS, and AWM to compare the repair cycle output before and after the fielding of CASS at AIMD, NAS Lemoore. (OPNAV 4790.2H)

APPENDIX F. DATA TABLES

FLT HRS	1990	1991	1992	1993	1994	1995	1996	1997
QTR 1	3945	1695	1996	1806	3547	3250	3063	4282
QTR 2	4510	1839	2034	1875	3392	3385	4525	3892
QTR 3	4581	2149	1459	1779	4299	3620	3784	4053
QTR 4	3867	2087	1483	1634	3352	3952	3486	3395

Table 11 Flight Hours

FAILURES	1990	1991	1992	1993	1994	1995	1996	1997
QTR 1	53	84	55	65	80	98	66	90
QTR 2	91	117	75	40	60	137	81	112
QTR 3	100	76	63	56	94	131	69	56
QTR 4	77	73	75	33	98	64	86	62

Table 12 Verified Failures

MTBF 1990-1997							
YEAR	QTR	742G100	742G200	742G300	742G400	742G600	SYSTEM
1990	QTR 1	263.00	187.86	1315.00	394.50	986.25	74.43
1990	QTR 2	121.89	214.76	751.67	265.29	451.00	49.56
1990	QTR 3	127.25	199.17	1527.00	157.97	509.00	45.81
1990	QTR 4	241.69	241.69	644.50	124.74	483.38	50.22
1991	QTR 1	54.68	169.50	188.33	58.45	339.00	20.18
1991	QTR 2	79.96	91.95	141.46	34.06	262.71	15.72
1991	QTR 3	79.59	119.39	195.36	214.90	214.90	28.28
1991	QTR 4	99.38	94.86	417.40	122.76	260.88	28.59
1992	QTR 1	90.73	199.60	181.45	285.14	399.20	36.29
1992	QTR 2	107.05	92.45	203.40	145.29	203.40	27.12
1992	QTR 3	54.04	121.58	364.75	132.64	162.11	23.16
1992	QTR 4	49.43	105.93	211.86	134.82	114.08	19.77
1993	QTR 1	86.00	129.00	451.50	112.88	180.60	27.78
1993	QTR 2	208.33	267.86	937.50	133.93	312.50	46.88
1993	QTR 3	127.07	148.25	444.75	93.63	254.14	31.77
1993	QTR 4	544.67	163.40	817.00	125.69	326.80	49.52
1994	QTR 1	177.35	443.38	443.38	147.79	177.35	44.34
1994	QTR 2	199.53	339.20	376.89	339.20	242.29	56.53
1994	QTR 3	179.13	214.95	537.38	226.26	186.91	45.73
1994	QTR 4	209.50	134.08	186.22	186.22	159.62	34.20
1995	QTR 1	125.00	191.18	203.13	180.56	154.76	33.16
1995	QTR 2	89.08	94.03	282.08	130.19	120.89	24.71
1995	QTR 3	116.77	106.47	157.39	329.09	113.13	27.63
1995	QTR 4	219.56	188.19	658.67	790.40	282.29	61.75
1996	QTR 1	161.21	340.33	255.25	340.33	180.18	46.41
1996	QTR 2	226.25	174.04	502.78	377.08	323.21	55.86
1996	QTR 3	189.20	222.59	540.57	199.16	630.67	54.84
1996	QTR 4	120.21	139.44	268.15	387.33	348.60	40.53
1997	QTR 1	133.81	214.10	305.86	251.88	611.71	47.58
1997	QTR 2	117.94	125.55	228.94	299.38	216.22	34.75
1997	QTR 3	225.17	506.63	337.75	405.30	506.63	72.38
1997	QTR 4	424.38	226.33	308.64	377.22	188.61	54.76

Table 13 MTBF for System and Components

AIMD MAINTENANCE MANHOURS			
		MHRS BEFORE/AFTER	
Subject	Year	1990-1993	1994-1997
1	QTR 1	17.75	12.25
2	QTR 2	21.56	12.49
3	QTR 3	15.83	17.77
4	QTR 4	7.86	16.97
5	QTR 1	12.94	21.23
6	QTR 2	12.81	23.33
7	QTR 3	14.66	17.92
8	QTR 4	20.35	29.08
9	QTR 1	13.87	17.97
10	QTR 2	12.68	15.05
11	QTR 3	18.63	28.06
12	QTR 4	21.41	32.46
13	QTR 1	19.84	17.32
14	QTR 2	15.74	15.76
15	QTR 3	15.63	24.71
16	QTR 4	23.11	13.90

Table 14 MMHRS

AIMD ELAPSE MAINTENANCE TIME (HOURS)			
		EMT BEFORE/AFTER	
Subject	Year	1990-1993	1994-1997
1	QTR 1	12.09	6.30
2	QTR 2	14.07	7.11
3	QTR 3	11.35	9.90
4	QTR 4	4.81	9.56
5	QTR 1	8.21	12.04
6	QTR 2	7.54	11.96
7	QTR 3	8.41	9.10
8	QTR 4	11.59	15.10
9	QTR 1	6.46	9.58
10	QTR 2	6.88	7.01
11	QTR 3	9.70	12.00
12	QTR 4	11.40	12.29
13	QTR 1	10.29	7.21
14	QTR 2	8.31	7.76
15	QTR 3	8.26	12.21
16	QTR 4	13.45	6.30

Table 15 EMT

AIMD AWAITING MAINTENANCE (HOURS)			
		AWM BEFORE/AFTER	
Subject	Year	1990-1993	1994-1997
1	QTR 1	24.44	10.25
2	QTR 2	33.21	0.50
3	QTR 3	36.35	10.72
4	QTR 4	26.66	0.23
5	QTR 1	58.32	0.69
6	QTR 2	7.02	23.58
7	QTR 3	31.34	101.38
8	QTR 4	1.82	189.76
9	QTR 1	15.68	44.36
10	QTR 2	2.37	49.18
11	QTR 3	16.50	45.10
12	QTR 4	17.72	64.42
13	QTR 1	4.28	25.18
14	QTR 2	22.77	4.78
15	QTR 3	21.64	32.95
16	QTR 4	8.70	33.58

Table 16 AWM

AIMD TURN AROUND TIME (DAYS)			
		TAT BEFORE/AFTER	
Subject	Year	1990-1993	1994-1997
1	QTR 1	15.83	4.24
2	QTR 2	28.62	14.02
3	QTR 3	16.92	7.91
4	QTR 4	7.21	21.60
5	QTR 1	18.54	15.18
6	QTR 2	19.47	10.92
7	QTR 3	6.05	10.05
8	QTR 4	22.87	8.16
9	QTR 1	3.73	29.77
10	QTR 2	9.73	1.43
11	QTR 3	20.11	6.17
12	QTR 4	15.83	13.70
13	QTR 1	43.72	6.09
14	QTR 2	3.05	3.65
15	QTR 3	3.03	12.43
16	QTR 4	46.06	7.31

Table 17 AIMD TAT days

AIMD REPAIR CYCLE					
YR	QTR	AIMD TAT	MHRS	EMT HRS	AWM HRS
1990	QTR 1	15.83	17.75	12.09	24.44
1990	QTR 2	28.62	21.56	14.07	33.21
1990	QTR 3	16.92	15.83	11.35	36.35
1990	QTR 4	7.21	7.86	4.81	26.66
1991	QTR 1	18.54	12.94	8.21	58.32
1991	QTR 2	19.47	12.81	7.54	7.02
1991	QTR 3	6.05	14.66	8.41	31.34
1991	QTR 4	22.87	20.35	11.59	1.82
1992	QTR 1	3.73	13.87	6.46	15.68
1992	QTR 2	9.73	12.68	6.88	2.37
1992	QTR 3	20.11	18.63	9.70	16.50
1992	QTR 4	15.83	21.41	11.40	17.72
1993	QTR 1	43.72	19.84	10.29	4.28
1993	QTR 2	3.05	15.74	8.31	22.77
1993	QTR 3	3.03	15.63	8.26	21.64
1993	QTR 4	46.06	23.11	13.45	8.70
1994	QTR 1	4.24	12.25	6.30	10.25
1994	QTR 2	14.02	12.49	7.11	0.50
1994	QTR 3	7.91	17.77	9.90	10.72
1994	QTR 4	21.60	16.97	9.56	0.23
1995	QTR 1	15.18	21.23	12.04	0.69
1995	QTR 2	10.92	23.33	11.96	23.58
1995	QTR 3	10.05	17.92	9.10	101.38
1995	QTR 4	8.16	29.08	15.10	189.76
1996	QTR 1	29.77	17.97	9.58	44.36
1996	QTR 2	1.43	15.05	7.01	49.18
1996	QTR 3	6.17	28.06	12.00	45.10
1996	QTR 4	13.70	32.46	12.29	64.42
1997	QTR 1	6.09	17.32	7.21	25.18
1997	QTR 2	3.65	15.76	7.76	4.78
1997	QTR 3	12.43	24.71	12.21	32.95
1997	QTR 4	7.31	13.90	6.30	33.58

Table 18   MTTR

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